Insolation and Temperature

Chapter 4

Energy, Heat and Temperature

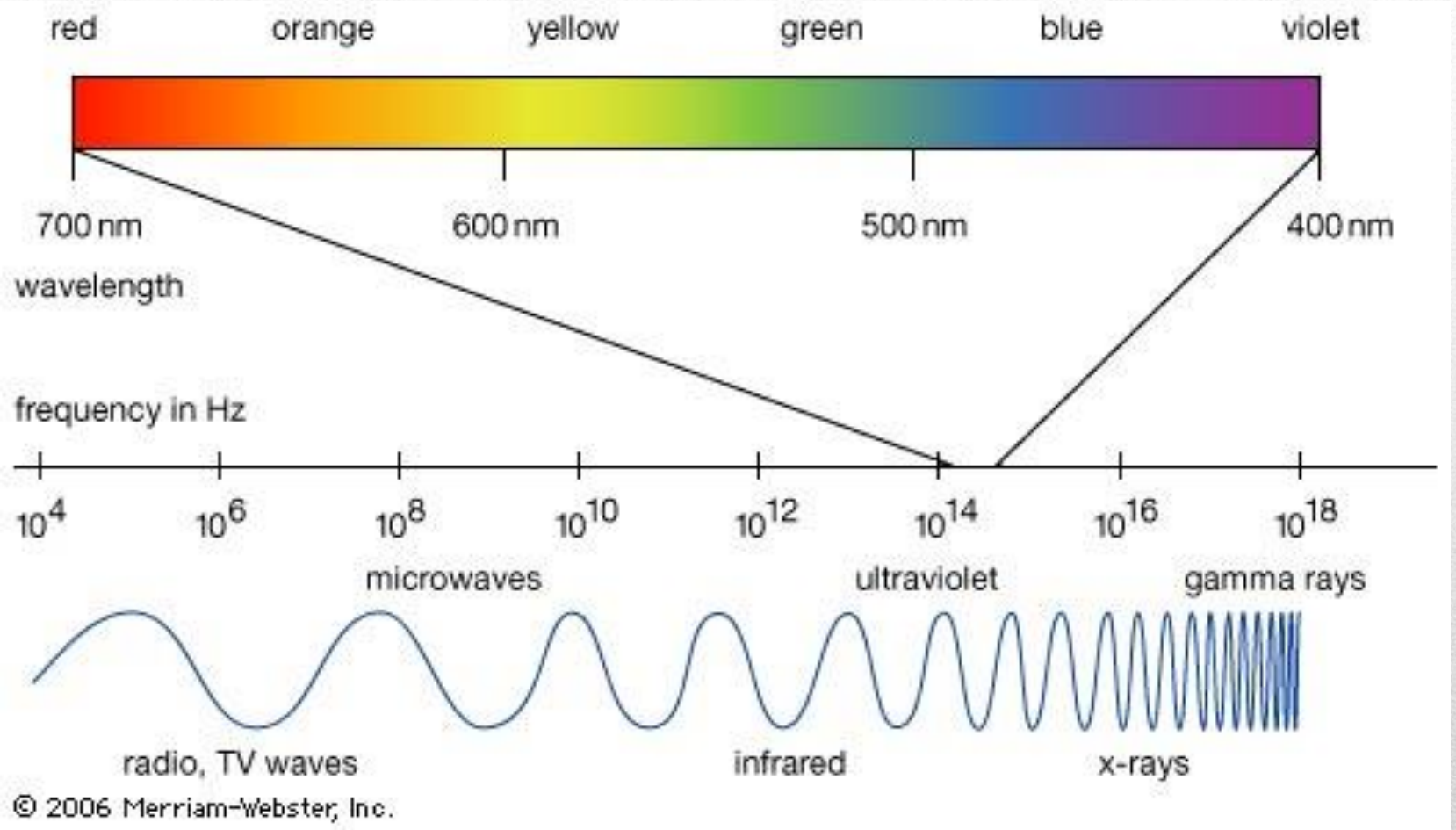
- Difference between **Heat** and **Temperature**
  - **Energy**
    - **Kinetic energy -- internal energy of molecule movement**
  - **Temperature**
    - **Temperature** – the average **kinetic energy** of the molecules in a substance
  - **Heat – energy that transfers from on object to another because of the difference in temperature**.

Energy, Heat and Temperature

- How to **measure temperature**
  - **Thermometers**—measures temperature
    - **Fahrenheit scale**
      - Used only in the US
      - Water Freezes at 32^{o}
      - Water Boils at 212^{o}
    - **Celsius scale**
      - Used throughout the rest of the world
      - Water freezes a 0^{o}
      - Water boils at 100^{o}
    - **Kelvin Scale**
      - Used in the scientific world

Solar Energy

- **Electromagnetic radiation**
  - **Energy from the Sun**
- **Electromagnetic spectrum**
  - **Different wavelengths of light**
    - **Visible light – 0.4 -0.7**
      - Violet, Blue, Green, Yellow, Orange, Red
    - **Ultra-Violet Radiation**
      - **Shorter waves than visible light** – 0.1- 0.4
      - **Mostly absorbed by the Ozone Layer**
    - **Infrared Radiation**
      - **Longer waves than visible light – 0.7 – 1.0**
    - **From Near Infrared to Thermal infrared**


red
orange
yellow
green
blue
violet
700 nm
600 nm
500 nm
400 nm
wavelength
frequency in Hz
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
microwaves
ultraviolet
gamma rays
radio, TV waves
infrared
x-rays
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Solar Energy

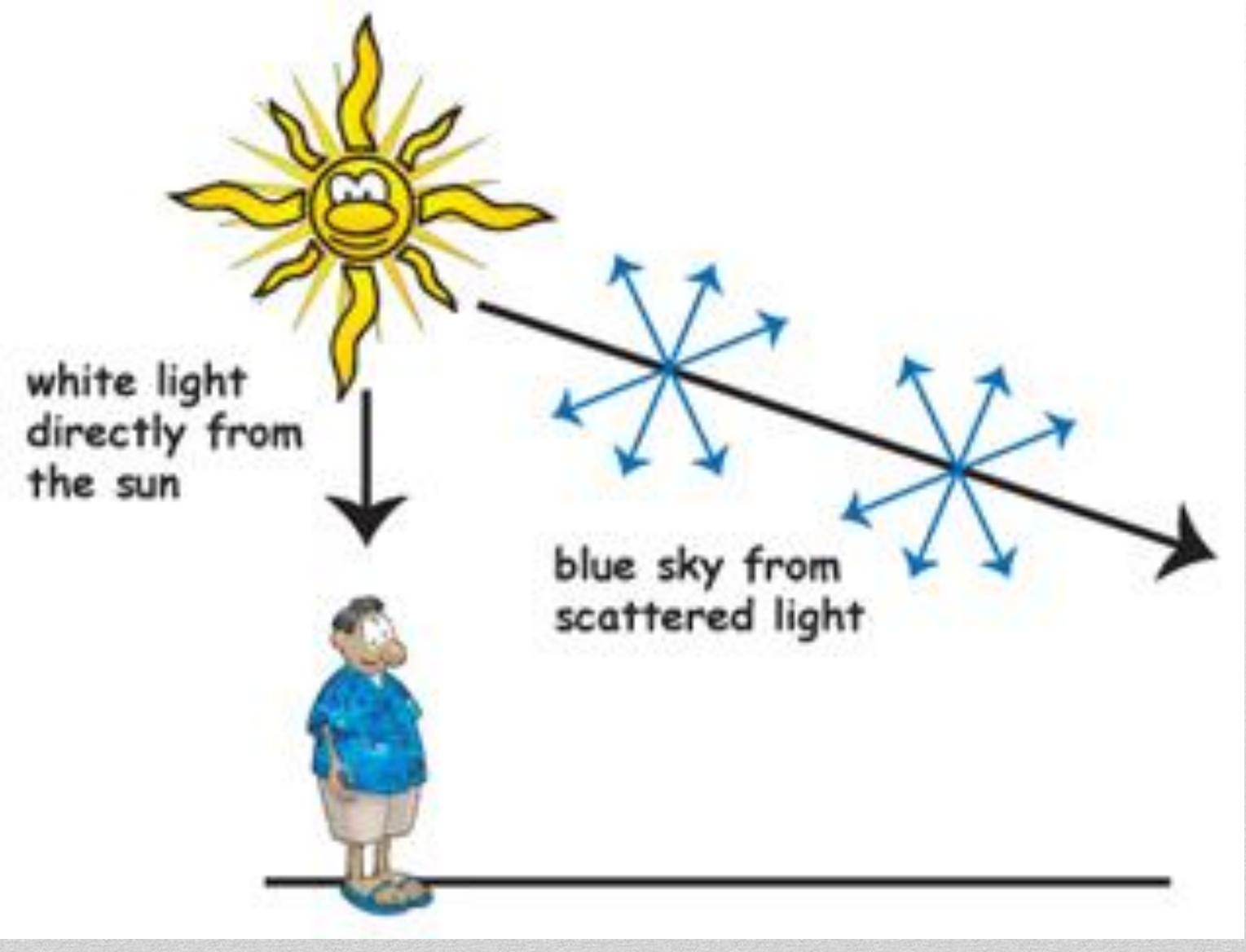
- **Radiation from Earth– Terrestrial Radiation**
  - Long wave Radiation – about 4 micrometers
- **Solar Radiation is at a constant level**
- When it hits the Earth's atmosphere,
  - **Some reflected back**
  - **The rest passes through the Atmosphere to be transformed into different energies.**

Basic Heating & Cooling Processes in the Atmosphere

- **Radiation or Emission**
  - The process by which **electromagnetic energy is emitted from an object**
    - **The hotter the object the more radiation it emits**
- **Absorption**
  - The **assimilation of electromagnetic waves by striking an object**.
    - **Different objects have different absorption abilities**
- **Reflection**
  - The **ability of an object to repel electromagnetic waves without altering either the object or the waves**

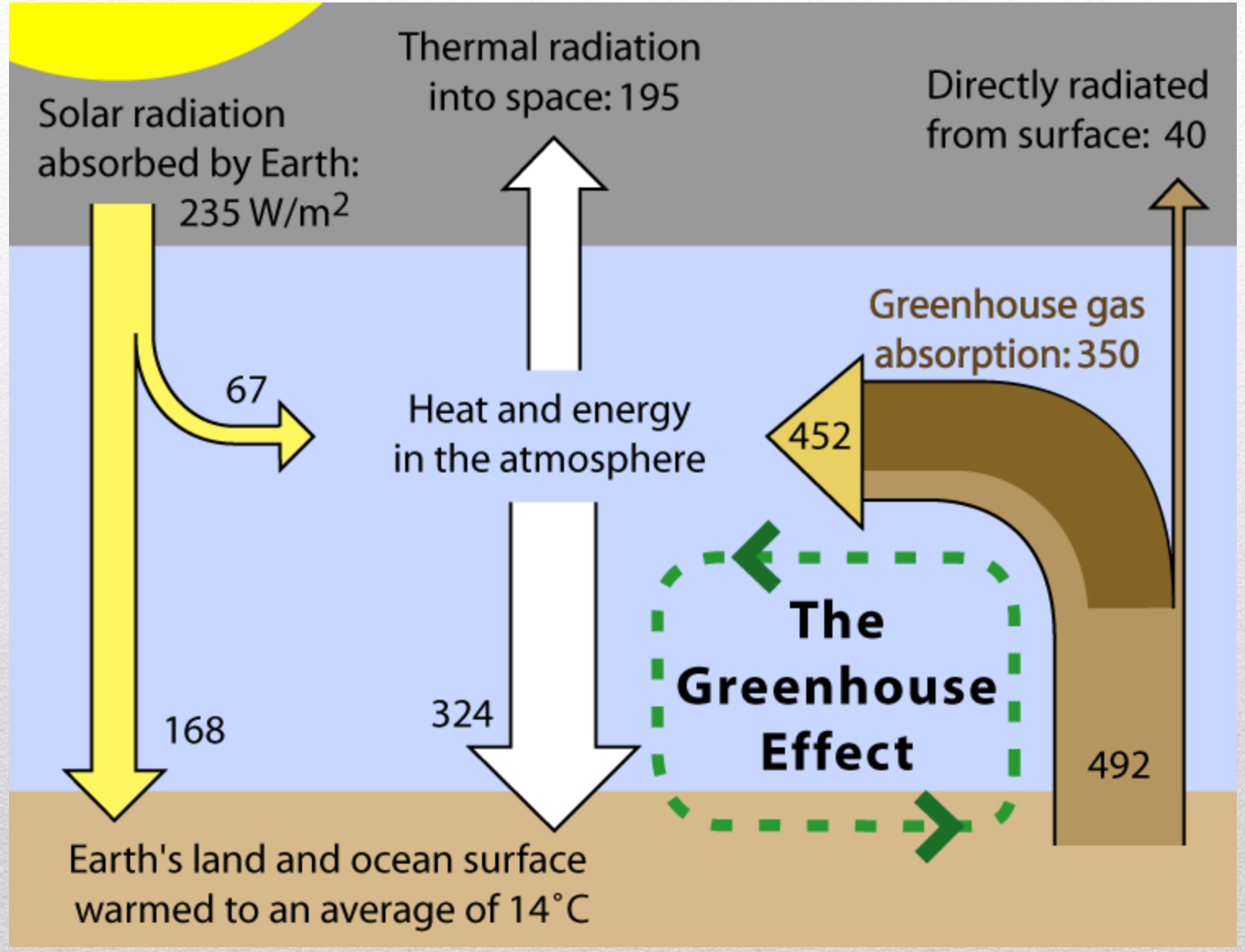
Basic Heating and Cooling Processes in the Atmosphere

- **Scattering**
  - The **act of deflecting or redirecting light waves** with gas molecules and particulate matter in the air.
  - Rayleigh Scattering – when the **shortest wavelengths are scattered (violet and blue)– causes the "blue sky"**
  - Sunset or Sunrise– **all the blue waves scattered as the energy passes through a longer atmosphere (larger angle) red, orange, and yellow left.**


white light
directly from
the sun
blue sky from
scattered light

Basic Heating and Cooling Processing in the Atmosphere

- **Transmission**
  - Process whereby **electromagnetic waves pass through a medium like class or clear water**
  - **The Greenhouse Effect– incoming short wave radiation enters an area, but the reflective longer waves cannot escape, causing the area to heat.**

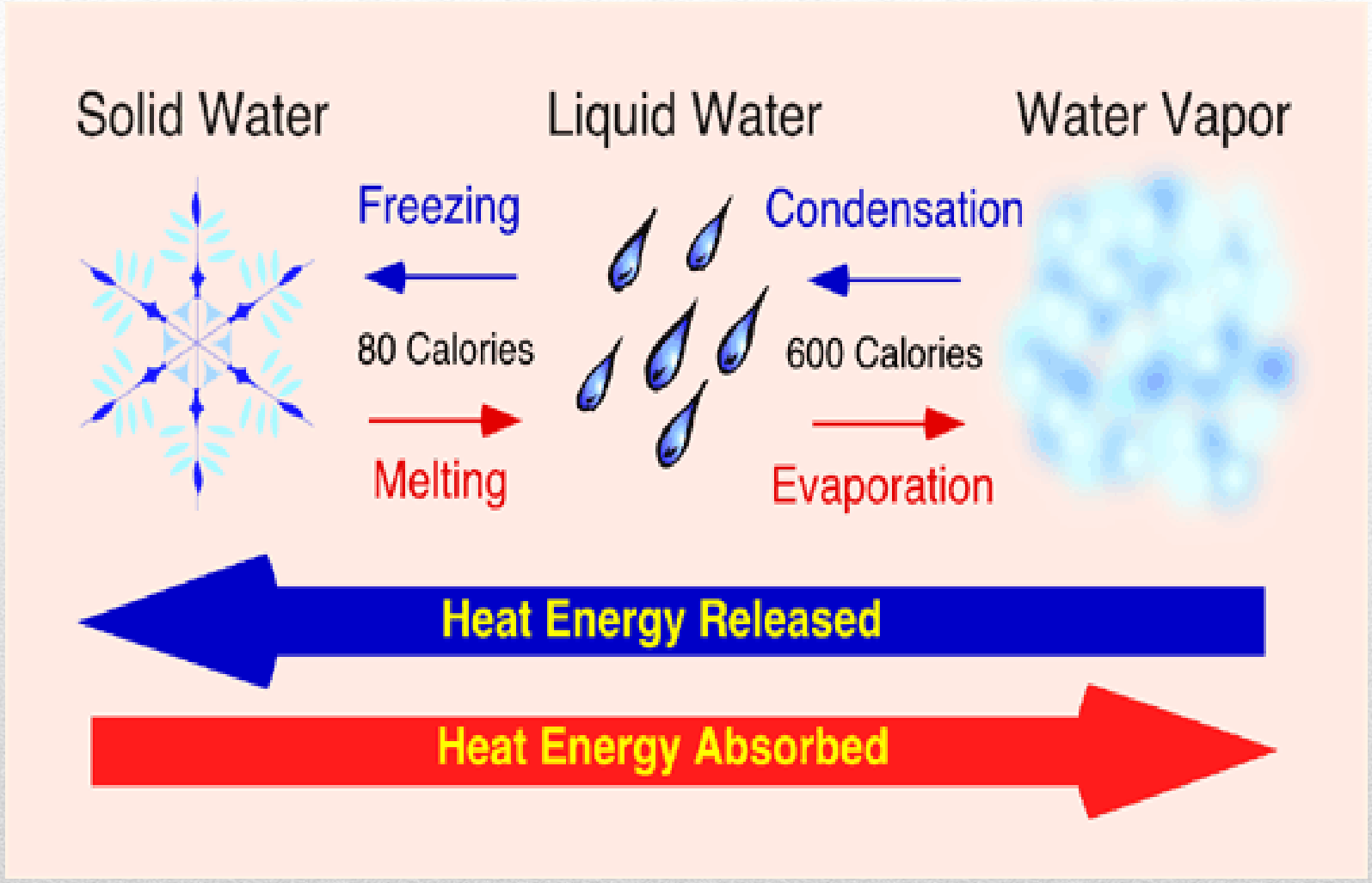

Thermal radiation into space: 195
Solar radiation absorbed by Earth: 235 W/m2
Directly radiated from surface: 40
Greenhouse gas absorption: 350
67
Heat and energy in the atmosphere
452
The Greenhouse Effect
168
324
492
Earth's land and ocean surface warmed to an average of 14°C

Basic Heating and Cooling Processing in the Atmosphere

- **Conduction**
  - **Movement of heat energy from one molecule to another without changes to their relative positions**
- **Convection**
  - **Heat is transferred from one point to another by the predominately vertical circulation of fluid, such as water or air.**
- **Advection**
  - **When the dominate direction of heat transfer is moving fluid horizontally**

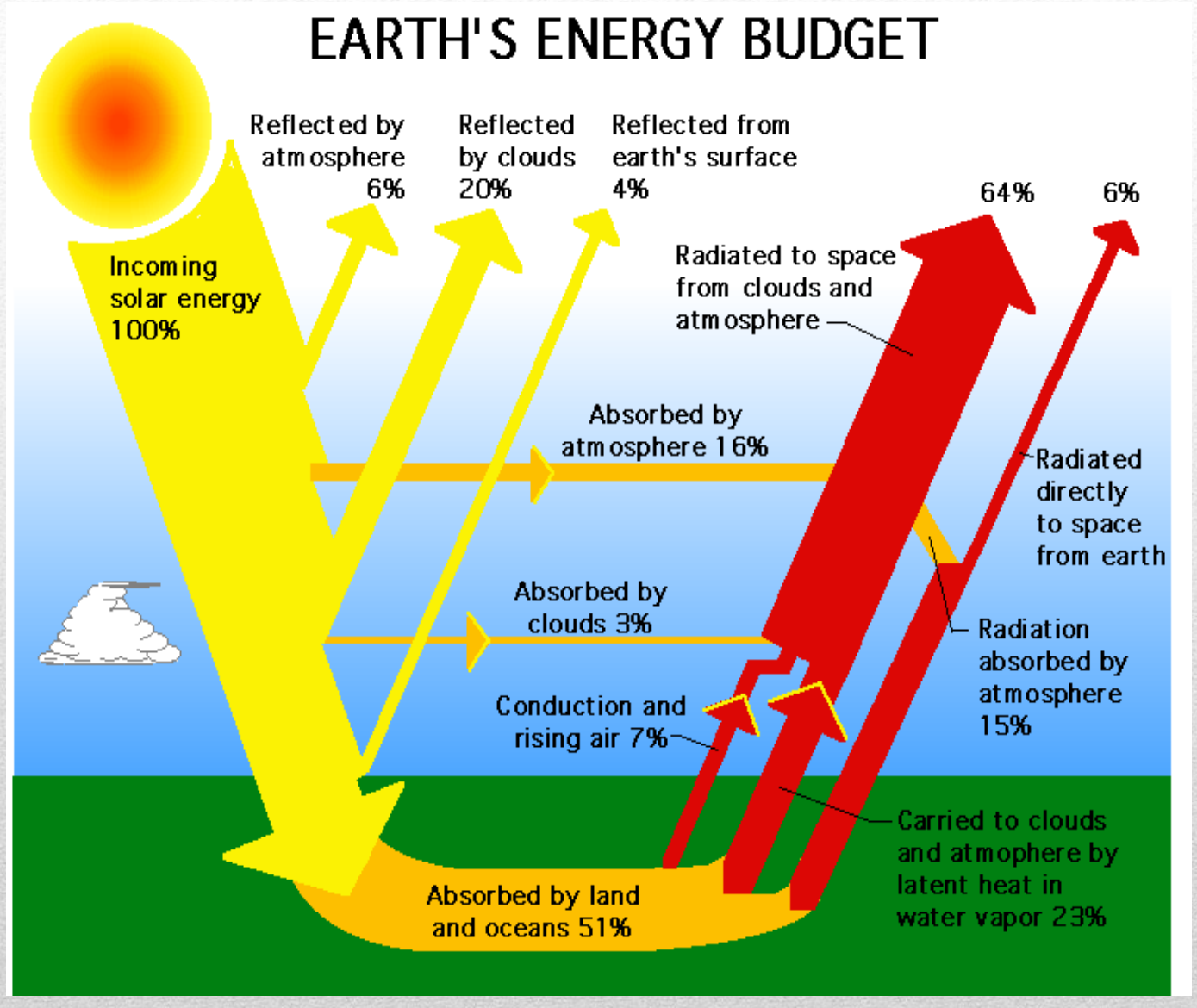
Basic Heating and Cooling Processes in the Atmosphere

- **Adiabatic Cooling and Warming**
  - Whenever air **ascends or descends, the temperature changes**
    - **Expansion: Adiabatic Cooling**
      - **As air rises the air cools**, as the molecules spread out loosing heat
    - **Compression: Adiabatic Warming**
      - **As air descends it is compressed**, the molecules collide and create heat
  - **Latent Heat**
    - **Storage or release of energy**
      - **Evaporation- liquid water changes to gases, energy is released, cooling happens**
      - **Condensation- gaseous water vapor turns to liquid energy is stored, heating happens**


Solid Water
Liquid Water
Water Vapor
Freezing
80 Calories
Melting
Condensation
600 Calories
Evaporation
Heat Energy Released
Heat Energy Absorbed

Heating of the Atmosphere

- **Global Energy Budget**
  - **100 units of Solar Radiation hits the atmosphere**.
    - Some absorbed
    - Some reflected
    - Some radiated
  - **Total units radiated out 100 units**
  - **Albedo**
    - **The reflective value of an object**
      - The higher the **Albedo value** the more radiation the object reflects.
- The **atmosphere is heated by *Earth radiation*** rather than the sun radiation.


EARTH'S ENERGY BUDGET
Reflected by atmosphere 6%
Reflected by clouds 20%
Reflected from earth's surface 4%
64%
6%
Incoming solar energy 100%
Radiated to space from clouds and atmosphere
Absorbed by atmosphere 16%
Radiated directly to space from earth
Absorbed by clouds 3%
Radiation absorbed by atmosphere 15%
Conduction and rising air 7%
Carried to clouds and atmophere by latent heat in water vapor 23%
Absorbed by land and oceans 51%

Variations in Heating by Latitude & Season

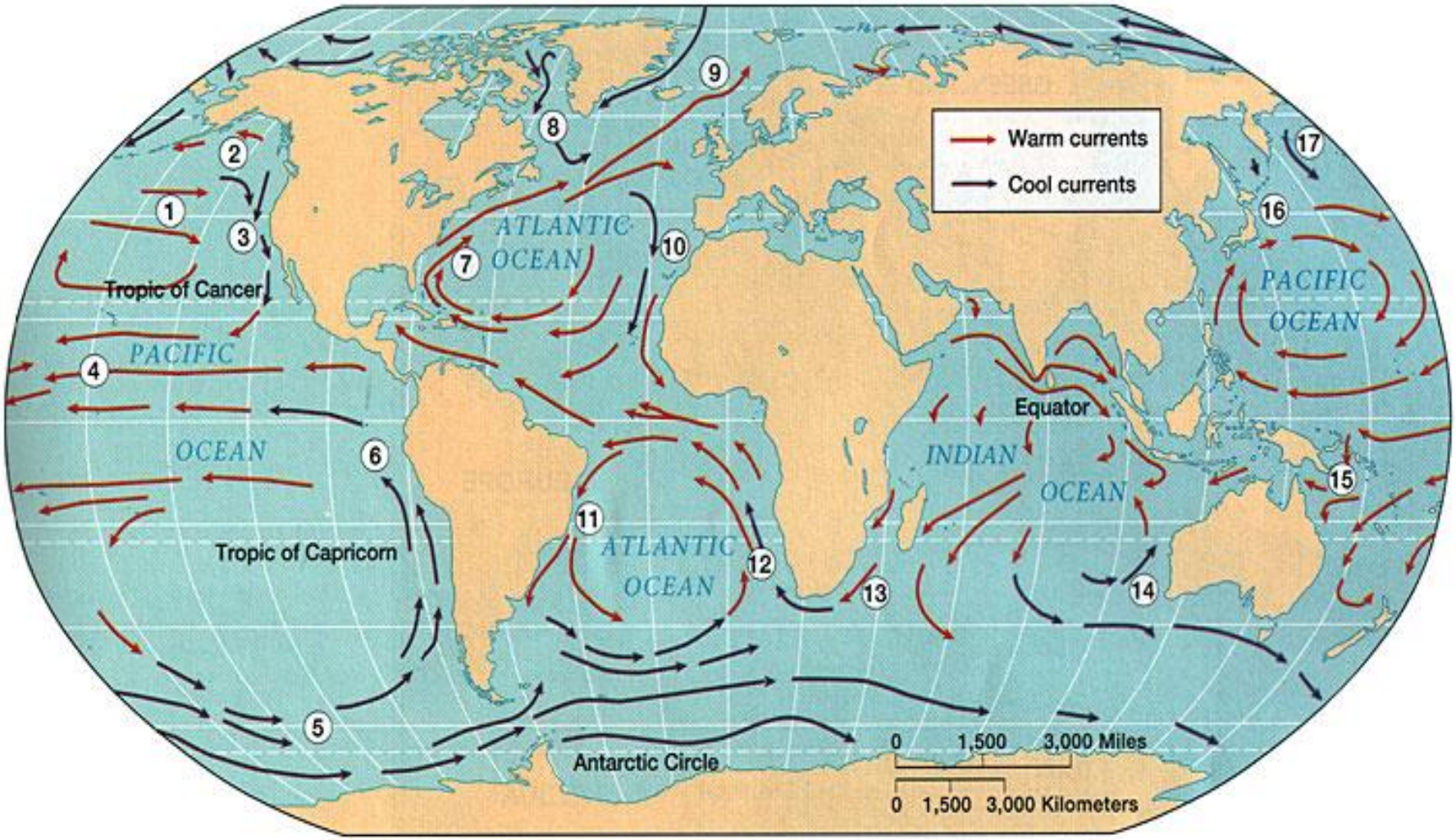
- **Angle of Incidence**
  - **Higher the angle (90%)**
    - The smaller the area of Earth receiving high energy (**warmer**)
  - **Lower the angle (10%)**
    - The larger the area of Earth receiving high energy (**cooler**)
- **Atmospheric Obstruction**
  - **The amount of atmosphere the energy passes through and the transparency of the atmosphere effects the energy received.**
- **Day Length**
  - **Duration of sunlight effects the energy received.**
- **Latitudinal Radiational Balance**
  - **Low Latitudes – more solar energy**
  - **High Latitudes – less solar energy**
  - **Balanced across the atmosphere**

Land & Water Contrasts

- **Heating**
  - **Specific Heat**
    - Amount of energy required to raise 1 gram of substance by 1 degree Celsius
  - **Transmission**
    - Water is a better transmitter of sunrays than land
  - **Mobility**
    - Water is high mobile and moves heat broadly and deeply
  - **Evaporative cooling**
    - Evaporative cooling is more prevalent over the water than over land. Latent heat is needed for this evaporation keeping the surface of water cooler.
- **Cooling**
  - Land cools more rapidly than water
- **Implications:**
  - ***Hottest and coldest areas of the earth are inland***

Mechanisms of Heat Transfer

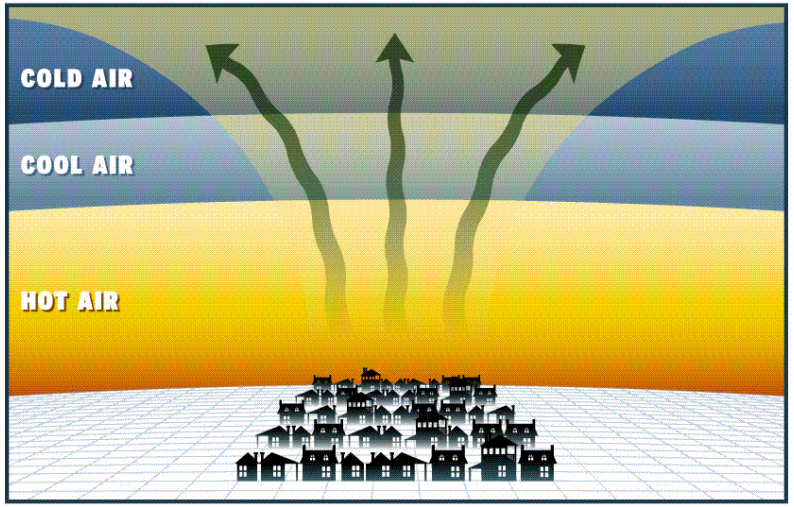
- **Atmospheric Circulation**
  - **Ocean Currents**
    - Close relation of the atmospheric circulation with ocean currents
    - Heat transfer by this circulation
- **Basic Patterns**
  - North Pacific, South Pacific, North Atlantic, South Atlantic, and South Indian
  - Continuous flow- West Wind Drift
- **Current Temperatures**
  - **Low Latitude currents – warm**
  - **Poleward – moving currents on western sides – warm**
  - **Northern Components – warm north and east**
  - **Southern Components – combined with the West Wind – usually cool**
  - **Equator-ward moving currents on the eastern side – cool**


Warm currents
Cool currents
ATLANTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
Tropic of Cancer
Tropic of Capricorn
Equator
Antarctic Circle
0 1,500 3,000 Miles
0 1,500 3,000 Kilometers
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

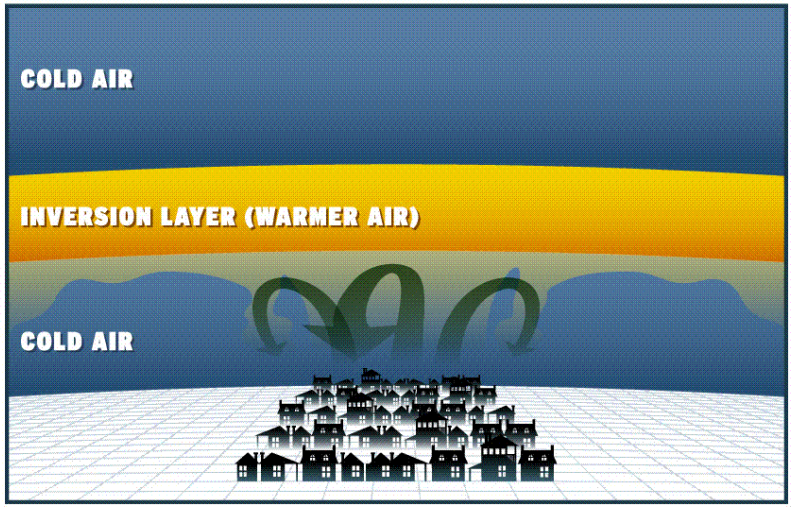
Vertical Temperature Patterns

- **Environmental Lapse Rate**
  - Observed trend of vertical temperature change in the atmosphere.
- **Average Lapse Rate** normal vertical temperature gradient of the troposphere.
  - **The average rate of temperature change is about 3.6 º over 1000 feet**.
- **Temperature Inversions**
  - **Temperature increases with altitude**
    - **Surface inversions**
      - **Radiation inversion** – rapid radiation cooling – long cold winter nights
      - **Advection inversion** – horizontal inflow of cold air– maritime air blowing in from the sea
      - **Cold-Air-Drainage inversion** – cold air sliding down a slope into a valley
    - **Upper Air Inversion**
      - **Result of air sinking from above** – subsistence inversion

NORMAL SITUATION



TEMPERATURE INVERSION



Global Temperature Patterns

- **Patterns of temperature** controlled by four factors– shown on maps with **Isotherms**
  - **Altitude**
  - **Latitude**
  - **Land-Water Contrasts**
  - **Ocean Currents**

Global Temperature Patterns

- **Altitude**
  - Complexity of the land, makes temperature depiction tricky
  - Use of the average lapse rate reduces the temperature at what it would be at sea level.
- **Latitude**
  - East-west trend of temperatures roughly along parallels.

Global Temperature Patterns

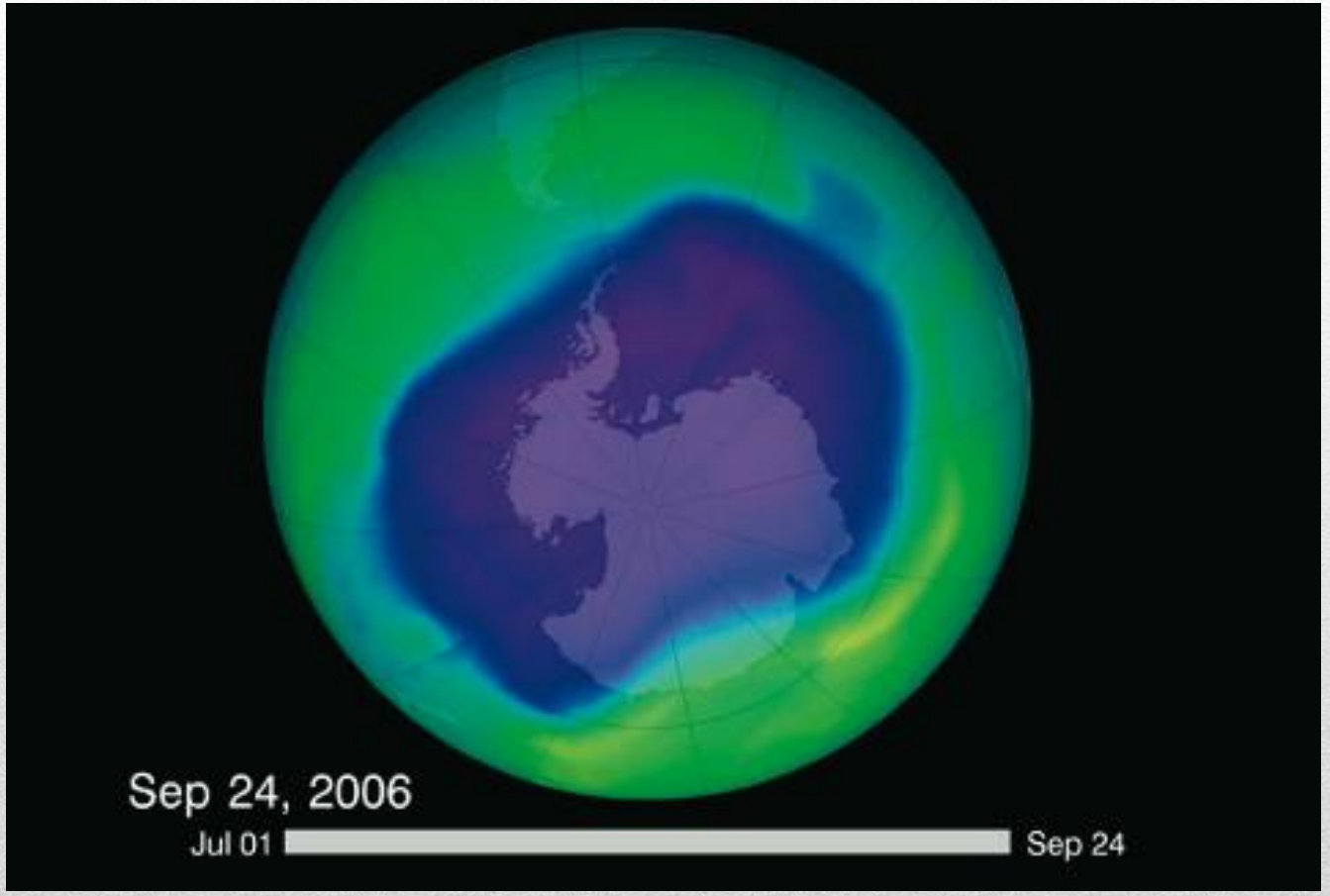
- **Land-Water Contrasts**
  - Differences apparent on a map.
  - Summer and winter extremes apparent over continents more than over the water.
  - In **southern latitudes, the isotherms are more regular because of the presence of more water.**

- **Ocean Currents**
  - Obvious bends in the isotherms are along the coastal waters
  - These follow the ocean currents, - warmer seasons over the warmer currents, cooler seasons over the cooler currents.

Global Temperature Patterns

- **Seasonal Patterns**.
  - Latitudinal shift of the isotherms
  - **Changes in the seasons**
    - Over **tropical areas little changes**
    - Over the **mid latitudes, basic seasons**
    - Over the **higher latitudes, seasons are cool, even in summer months**
- **Average Temperature Range**
  - The **average temperature between the warmest and coldest months**

Global Warming and Greenhouse Effect



What do you think about this highly controversial happening